

Aneurysmal Subarachnoid Hemorrhage in Pregnancy: Literature Review

Corneliu Toader^{1,2}, Bogdan Gabriel Bratu², Ligia Tataranu^{2,3}, Andrei Alexandru Marinescu¹, Alexandru Vlad Ciurea^{2,4,5}

1. Department of Neurosurgery, National Institute of Neurology and Neurovascular Diseases, Bucharest, Romania
2. "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania
3. Department of Neurosurgery, Emergency Clinical Hospital Bagdasar Arseni, Bucharest, Romania
4. Department of Neurosurgery, Sanador Clinical Hospital, Bucharest, Romania
5. Honorary Member of Romanian Academy, Medical Science Section, Bucharest, Romania

Abstract. Aneurysmal subarachnoid hemorrhage is a neurosurgical emergency, representing a major factor in the morbidity and mortality of mother and fetus, and requires prompt intervention and multidisciplinary care. There are no standardized guidelines to date on management and treatment of this clinically rare scenario and the main issues are debated in recent literature. This review summarizes relevant publications of the past 20 years and compiles key concepts in the treatment of this challenging condition. Early diagnosis and treatment are of great importance and pregnant patients should be treated the same as non-pregnant patients that suffer an aSAH. It often depends on the caregiver's experience which surgical intervention is chosen. Moreover, most patients will suffer an aSAH during the third trimester, even though the outcome for such patients may potentially be disastrous, screening for intracranial aneurysms in high-risk pregnant women is still controversial

Keywords: aneurysmal subarachnoid hemorrhage, pregnancy, childbirth, review

Introduction

Aneurysmal subarachnoid hemorrhage (aSAH) in pregnancy, occurs when an aneurysm bursts and leaks into the space surrounding the brain, leaving both mother and fetus exposed to multiple risks and complications. aSAH during pregnancy is a relatively uncommon scenario, but a neurosurgical emergency which requires rapid intervention and multidisciplinary management [1]. The literature on this topic is limited, containing mostly case series and case reports, describing overall very similar approaches for treating these challenging cases. But no single hospital unit has enough cases to gain sufficient experience so that management strategies for patients suffering from this condition might be improved [2]. Incidence is only between 0.01 and 0.05%, but it has a high maternal mortality, causing 5% to 12% of total mortality in pregnancy.

Serious morbidity for mother and/or fetus is another possible outcome [3]. The current consensus is that because of the low incidence, treatment in pregnancy should not differ from non-pregnancy cases [4]. This article reviews the most current literature, summarizing key concepts of diagnosis, management approaches and outcomes for aneurysmal subarachnoid hemorrhage (aSAH) during pregnancy, childbirth and the postpartum period.

Corresponding author: Assoc. Prof. Ligia Tataranu MD. PhD. ltaranu@gmail.ro

Received: February 28, 2023; Accepted: March 30, 2023; Published June 30, 2023

Citation: Toader C., Bratu B.G., a Tataranu Ligia, Marinescu A.A., Ciurea A.V.: Aneurysmal Subarachnoid Hemorrhage in Pregnancy: Literature Review. Journal of Surgery [Jurnalul de chirurgie]. 2023; 19(2): 111 - 120. DOI: 10.7438/JSURG.2023.02.02

Copyright: 2023.© Toader C.: This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited

Materials and Methods

We reviewed the most relevant literature of the past 20 years which focuses on the treatment of patients that suffered an aSAH during pregnancy.

On February 15, 2023, we performed an advanced search on PubMed with the following search formula: ((aneurysmal subarachnoid hemorrhage) OR (aSAH)) AND ((antenatal) OR (maternal) OR (pregnancy) OR (pregnant)), and eligible articles were case series, case reports and literature reviews. Initially, PubMed showed 75 articles. The titles of each article were reviewed and after we applied the exclusion criteria, being others pathologies beside aSAH in pregnant patients, 46 studies included cases of aneurysmal subarachnoid hemorrhage in pregnancy or overviews of the current management in the literature regarding this issue. (Figure 1)

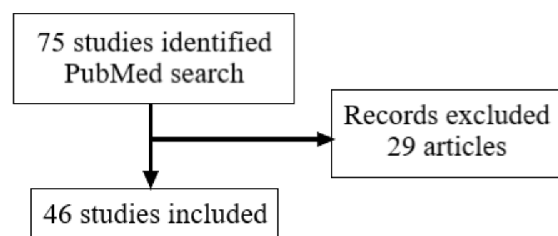


Figure 1 – Overview of our review's studies selection

Epidemiology

Some authors state that the incidence of aSAH increases during pregnancy [2] while others argue that there is no clear increased risk compared to the general population [3]. However, there is unanimity in the literature, that increasing gestational and maternal age seems to be associated with a higher risk of aSAH, with over 50% of ruptures happening during the third trimester [5] caused by increased plasma volumes, pregnancy-induced hypertension and hemodynamic variations [6].

Physiopathology

Subarachnoid hemorrhage (SAH) more commonly occurs due to non-aneurysmal factors, but is considered to be of higher mortality and worse prognosis when caused by aneurysm rupture [6]. Intracranial aneurysms (IA) in pregnant women occur when smooth muscle cells inside the vessel walls undergo apoptosis, the internal elastic lamina is being disrupted or collagen and elastin are broken down. All these events lead to formation of aneurysms which are typically saccular in shape and located in the anterior circulation [7].

The pathogenesis of aneurysms is much more complicated and many questions remain unanswered to this day. For example, even though hormones can cause venous and arterial media and intima to remodel, eventually forming an aneurysm, pregnant women who have increased hormonal levels, especially estrogen, are thought to be protected against IA rupture, and thus against the occurrence of aSAH.

Factors such as stroke volume, blood volume and cardiac output increase during the end of pregnancy serve as an explanation for why there is increased IA rupture rate in the third trimester. Other causes may be the appearance of gestational hypertension, pre-eclampsia and even the rise in arterial pressure during childbirth. Additionally, there are risk factors such as smoking, alcohol and drug use, diabetes mellitus and sickle cell disease or African-American and Hispanic descent [7].

Diagnosis

Pregnant patients suspected with aSAH should be admitted to an intensive care unit and examined by maternal-fetal medicine, obstetrics and neurosurgery. They generally present with the same clinical features as the general population. A patient is admitted due to a suddenly appearing, severe headache, which can be associated with many other common aSAH symptoms

such as nausea or vomiting [8]. This headache might even occur days or up to weeks in advance of admission, suggesting a future aneurysmal rupture. In other cases, symptoms might be mild on admission, which makes it difficult to diagnose the aSAH [7]. Other signs that are specific for aSAH are meningism which commonly manifests several hours after aSAH, and intraocular hemorrhage which is seen on ophthalmoscopy [2].

Differential diagnosis of aSAH is made with neurological disorders that can occur simultaneously such as eclampsia, posterior reversible encephalopathy syndrome (PRES), adenohypophysis apoplexy, dural venous sinus thrombosis, and tension headaches. Some of the mentioned conditions have a similar manifestation to aSAH, but are treated very differently [7].

Imaging investigation after suspicion of aSAH is the same as for nonpregnant patients. To obtain the diagnosis, a computed tomography (CT) is usually indicated first, but can be superseded by magnetic resonance imaging (MRI), which might differentiate aSAH from eclampsia [8]. Regardless of which imaging technique is eventually chosen, it is important to know that sensitivity is the highest within hours after aSAH onset, but decreases over time. For occult cases in which both CT and MRI are inadequate or simply negative for aSAH, a lumbar puncture should be carried out [7].

There is an ongoing discussion going on in the literature concerning fetal radiation doses. But it IS WORTH MENTIONING that standard head CTs without contrast are not high enough to cause any congenital anomalies. The same appears to be the case for radiation doses of cerebral digital subtraction angiography (DSA), a diagnostic study that might soon be replaced by spiral

CT-angiography. When performing CT angiography or any other investigation that might expose the fetus to radiation, it is advisable to use lead shielding as protection [2].

Screening for unruptured IAs in high-risk patients by magnetic resonance angiography (MRA) is controversial, but might be of benefit for patients who present with chronic hypertension or past history of cerebrovascular disease. Nevertheless, discussions should be had with patients that consider to have children but in whom an unruptured IA is found incidentally [9].

Management

The management and treatment of pregnant patients suffering from aSAH is a team effort. Obstetricians and gynecologists, anesthesiologists, neuroradiologists and neurosurgeons all have to work together to achieve the best possible outcome for the patient. The survival rate for patients treated surgically is higher than for those treated conservatively. The mode of treatment depends on multiple patient- and aneurysm-specific factors, such as maternal health and neurological status or IA type, size and shape or location. The physician's experience with either treatment modality is a decisive factor when aiming for the best patient outcome [5].

The mother's outcome may depend also on the mother's age, Hunt and Hess scale score, Glasgow Coma Scale at arrival, IA treatment modality, and timing and mode of delivery. For the fetus, the outcome is better, if delivery occurs before surgical treatment, thus avoiding poor uterine perfusion which occurs during aneurysm surgical treatment, exposing the fetus to multiple risks, such as hypoxia, dehydration and acidosis, eventually leading to multiple organ failure and death. Furthermore, early delivery prevents complications related to anesthesia

or maternal blood pressure changes [10]. (Table 1)

Endovascular coiling

For patients with good clinical status, Guglielmi detachable coils (GDC) should be used for treating the ruptured IA. Even though GDC is usually placed with the patient being under general anesthesia, which is accompanied by its own hazards, successful awake endovascular treatment of ruptured IAs has been done before, thereby eliminating any hazards concomitant with general anesthesia. However, aneurysms with a wide neck or a location such as in the middle cerebral artery (MCA) can't be treated using GDCs [4].

Moreover, complications can arise from systemic anticoagulation, which is necessary for lowering the risk of thrombo-embolic complications during the embolization, and is used in many centers, where heparin treatment is done routinely. Also, treatment with antiplatelet agents, such as during dual antiplatelet therapy (DAPT), is associated with higher risk of placental abruption, peri- or post-partum injury and hemorrhage in pregnant patients. The same does not apply to low dose aspirin however, which may even be advantageous for patients over 12 weeks into their pregnancy [11].

More reasons to choose endovascular coiling over clipping are that it avoids major dynamic changes in the circulation of the mother [12]. The irradiation exposure of the fetus during endovascular coiling is also not critical and does not cause hereditary diseases of the fetus. Other factors affecting

the choice of the surgical procedure are the risk of epilepsy and cognitive decline, which are lowered by endovascular coiling, or the probability of rebleeding and failure to obliterate which are increased for example in cases in which the coils are not tightly packed inside the IA [13].

A rare complication that might occur while performing embolization of the IA, is when delivery begins spontaneously. In such cases emergency cesarean section (CS) is needed and care should be taken to manage the hemorrhage, which is a complication due to the previously administered anticoagulants [4].

Microsurgical clipping

Due to many of the aforementioned problems with endovascular coiling, clipping is preferred if it is safe to treat the aneurysm with either procedure (9). It is more invasive and requires an open craniotomy, but this makes aneurysmal exclusion visible and more reliable in the long run. It also allows for potential management of a different but concomitant neurosurgical condition during surgery, but increases hospital stays afterwards [2]. It allows for aneurysm treatment and delivery by cesarean section (CS) to be performed in one operating room or during a single session, which is a big advantage over GDC, especially in the previously mentioned scenario in which onset of delivery occurs spontaneously during the ongoing surgical intervention for an aSAH [12]. (Table 1)

Table 1: GA - Gestational Age, MCA - middle cerebral artery, PCOM - posterior communicating artery, ACOM - anterior communicating artery, PICA - posterior inferior cerebellar artery, AICA - anterior inferior cerebellar artery, ICA - internal carotid artery, PCA - posterior cerebral artery VA - vertebral artery, BA - basilar artery, VB - vertebrobasilar artery, PerA - pericallosal artery, CO - carotid-ophthalmic artery, SHA - superior hypophyseal artery, PP - postpartum, CS - cesarean section, VG - vaginal, A - abortion, GOS - Glasgow Outcome Scale.

First Author	Nr. Cases	GA (weeks)	Diagnosis (localization of aneurysm)	Delivery	Outcome child	Maternal Outcome (GOS)	Surgical Treatment	Mother Age (years)
--------------	-----------	------------	--------------------------------------	----------	---------------	------------------------	--------------------	--------------------

Kizilkilic et al., 2003 [8]	3	10	PCOM	A	dead	5	embolization	25
		18	ICA	CS	healthy	5	embolization	39
		28	ACOM	CS	healthy	5	embolization	26
Georgantopoulou et al., 2003 [15]	1	9	PCOM	CS	healthy	5	clipping	32
Roman et al., 2004 [16]	8	37	ICA	CS	healthy	5	embolization	28
		34	ICA	CS	healthy	5	clipping	27
		12	ICA	VG	healthy	5	clipping	37
		31	ICA	CS	dead	5	clipping	30
		32	MCA	CS	dead	1	none	30
		24	CO	VG	healthy	5	embolization	27
		38	MCA	-	dead	1	none	40
		32	CO	CS	unhealthy	1	clipping	33
Riviello et al., 2004 [17]	1	36	PerA	CS	healthy	5	embolization	37
Nelson et al., 2005 [18]	1	16	ACOM	VG	healthy	5	clipping	19
Darbhamulla et al., 2007 [19]	1	31	ACOM	CS	-	5	embolization	22
Duggan et al., 2008 [20]	1	-	AICA	CS	healthy	5	none	22
Groenestege et al., 2009 [21]	7	10	ICA	A	dead	4	clipping	32
		17	ICA	CS	healthy	5	clipping	23
		28	-	-	dead	1	none	31
		38	PCA	CS	healthy	1	none	32
		PP	ACOM	VG	healthy	3	clipping	36
		PP	MCA	CS	healthy	4	clipping	32
		PP	PCOM	VG	healthy	4	clipping	41
Pumar et al., 2010 [22]	1	32	BA	CS	healthy	5	embolization	30
Couldwell et al., 2010 [23]	1	18	MCA	CS	healthy	5	clipping	26
Elwatidy et al., 2011 [24]	2	36	ICA	CS	healthy	5	clipping	26
		22	MCA	VG	healthy	5	embolization	24
Doğan et al., 2011 [25]	1	PP	ICA	CS	healthy	5	embolization	38
Mavromatidis et al., 2011 [26]	1	-	ACOM	CS	healthy	5	none	30
Ferreira et al., 2012 [27]	1	32	VB	-	-	5	clipping	40

Guida et al., 2012 [28]	4	34	ACA	-	-	5	embolization	37
		37	MCA	-	-	1	embolization	34
		32	ACA	-	-	1	embolization	41
		33	BA	-	-	5	embolization	28
Bateman et al., 2012 [6]	3	3rd trimester	PCOM	-	-	1	clipping	41
		PP	CO & SHA & PCA	-	-	4	clipping	31
		PP	ICA	-	-	5	none	42
Tarnaris et al., 2012 [13]	1	29	PCOM	CS	healthy	4	embolization	21
Kataoka et al., 2013 [4]	5	26	VA-PICA junction	CS	healthy	5	clipping	20
		30	ACOM	CS	healthy	5	clipping	34
		24	MCA	CS	healthy	5	clipping	36
		31	ACOM	CS	healthy	5	clipping	34
		28	BA	-	dead	1	-	42
Surico et al., 2014 [29]	1	27	ICA	CS	healthy	5	embolization	-
Kim et al., 2014 [30]	1	16	PICA	CS	healthy	5	embolization	34
Wawrzyniak, 2015 [31]	1	22	ICA & PCA	CS	healthy	1	none	30
Atallah et al., 2015 [32]	1	36	PCOM	CS	healthy	5	clipping	38
Goto et al., 2015 [33]	1	PP	MCA	CS	healthy	5	clipping	34
Robba et al., 2016 [3]	7	28	PCA	CS	healthy	5	clipping	27
		21	MCA	VG	healthy	4	clipping	29
		28	MCA	CS	healthy	5	clipping	30
		35	ACOM	CS	healthy	4	clipping	31
		39	MCA	CS	healthy	4	clipping	21
		20	MCA	VG	healthy	5	clipping	31
		24	ICA	CS	healthy	4	clipping	36
Dinc et al., 2016 [34]	1	13	PICA	VG	healthy	5	none	26
Mehrotra et al., 2017 [35]	1	32	PCA	VG	healthy	5	none	26
Mehrotra et al., 2017 [36]	1	32	ICA	VG	healthy	5	clipping	22
Fritzsche et al., 2017 [1]	4	30	MCA	CS	healthy	5	clipping	37
		36	MCA	CS	-	1	-	31
		34	PCOM	CS	healthy	5	embolization	30
		27	MCA	VG	healthy	5	clipping	25

Tomar et al., 2017 [37]	1	16	ACA	CS	healthy	5	clipping	25
Hu et al., 2018 [38]	1	34	PCOM	CS	healthy	5	none	33
Vatsa et al., 2019 [39]	1	28	PCA	CS	healthy	5	embolization	25
Onat et al., 2019 [40]	1	34	MCA	CS	healthy	1	clipping	37
Esmaeilzadeh et al., 2020 [41]	2	29	PICA	CS	healthy	1	embolization	45
		25	PICA	CS	healthy	1	embolization	40
Karabuk et al., 2020 [42]	1	27	ACOM	CS	healthy	2	clipping	31
Assoumane et al., 2020 [43]	1	38	CO	CS	healthy	5	embolization	41
Hironaka et al., 2020 [44]	1	31	PCOM	CS	healthy	5	clipping	34
Xie et al., 2021 [45]	1	32	ICA	CS	healthy	5	embolization	28
Hughes et al., 2021 [47]	1	33	MCA	CS	healthy	4	embolization	50

During the procedure low blood pressure has to be maintained and induced hyperventilation used, to control intracranial pressure, which can have negative effects on the fetus. Therefore, delivery by CS is usually performed before clipping the IA. Surgery associated complications that have been reported to affect the mother are postpartum cardiomyopathy, symptomatic cerebral vasospasm and rebleeding [9].

Other considerations for management

Before, during and after surgery, it is important to position the patient in a left lateral position, thereby diminishing the possibility of the fetus compressing on the mother's inferior vena cava, which otherwise leads to redistribution of the blood flow to the fetus which is associated with negative effects [8]. Also, the temperature should be controlled, but without inducing therapeutic hypothermia, which might otherwise cause fetal death. Blood pressure management is also important, but antihypertensive drugs such as diuretics should be avoided. They are used in the general population to lower the risk of aneurysm rupturing during an

operation, but can diminish uterine perfusion, maternal dehydration and subsequent hypotension, eventually leading to fetal injury. Temporary clips proximally to the IA should rather be used to avoid IA rupturing [7].

The main goal in the treatment of aSAH is to avoid re-bleeding, which has a mortality rate of 50-70%. Additionally, mortality increases with each successive re-rupture. For safe treatment of hydrocephalus and protection in the case of re-rupture of an IA during surgery, one should consider placing a temporary extraventricular drain (EVD) catheter or creating a ventriculoperitoneal shunt (VPS). CSF diversion can be long-term, without any negative effects on the peripartum period [7].

Controlling the blood pressure is difficult, especially in pregnant patients. Triple-H therapy (hypertension, hypervolemia, and hemodilution) is used in the general population after management of aSAH [4]. Permissive short-term hypertension is thought to act against cerebral vasospasm (CVS) from occurring,

but might have effects on the placenta of pregnant patients as well as on the fetus. These effects express themselves similar to those of pre-eclampsia [14]. During the peak of CVS, which is measured by transcranial doppler (TCD) ultrasound, systolic blood pressure (sBP) should be maintained at around 150 mmHg and after discussing possible side effects with the patient, even up to 180 mmHg. The management of sBP also depends on the intervention chosen for treatment of the ruptured IA. With endovascular treatment, prolonged hypertension is shorter or not needed at all.

Managing the risk for cerebral vasospasm. CVS occurring in aSAH is important, because it is a factor that is contributing to morbidity and mortality. It causes delayed cerebral ischemia (DCI) by an unknown mechanism, which possesses the same complications such as permanent neurological deficit that are associated with any other stroke, and may even lead to death, only rarely resolving in a good outcome. The incidence rate of CVS in pregnant patients is supposed to be similar with that in non-pregnant patients. Nevertheless, it needs to be further studied when associated with pregnancy [2].

To prevent cerebral ischemia from happening in CVS after aSAH in non-pregnant patients, calcium channel blockers (CCB) may be given. Nimodipine is given prophylactically for 21 days from the onset of aSAH, while verapamil and nicardipine, may be given in emergency situations where CVS is symptomatic. In the latter case, early administration of intra-arterial agents through endovascular intervention can be considered. However, these drugs should be administered carefully in pregnant patients or not at all in cases with low-risk for CVS [7].

Delivery modes

Whether or not urgent delivery is needed depends on the patient's gestation

week and other factors and is therefore to be managed differently from one case to another. If the gestation week is less than 24 weeks, one should aim to rapidly and successfully treat the aneurysm, allowing the pregnancy to progress to term, in order for later vaginal delivery [8]. Caesarean section (CS) should be considered for gestation week 34 and later (Table 1), while for patients in a gestation week between 24 and 4 weeks, treatment options should be considered on an individual case basis, with regard to the fetal and maternal status [9]. After coil embolization of a ruptured IA, cesarean section (CS) should be considered in high-grade aSAH if the fetus reached sufficient maturity, and vaginal delivery is preferred in low-grade aSAH. The use of oxytocic agents or amniotomy is a safe way to bring about labor, also for patients previously treated for an aSAH [2].

Throughout the entire treatment of aSAH in a pregnant patient, fetal heart rate monitoring is essential, in order to better estimate fetal health. Also, multidisciplinary teams are helpful for guidance on further patient management [7].

Conclusions

A patient suffering an aSAH during pregnancy is in a high-risk state and difficult to treat. The correct management and treatment modality for this scenario is still controversial and no expert guidelines exist to date, due to the rarity with which these cases occur. Treatment should be initiated as early as possible after aSAH discovery, by a multidisciplinary team, to yield a better prognostic outcome for both mother and fetus. The time and mode of delivery and modality of surgical management differs from case to case, depending on multiple maternal and fetal related factors. Nevertheless, the general consensus is to treat pregnant patients the same as non-pregnant patients. Still, further research in this field

has to be conducted, especially comparing multicentric data to gain better understanding of the optimal treatment strategies, thereby lowering the high maternal morbidity and mortality that is associated with this condition.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Fritzsche FS, Regelsberger J, Schmidt NO. Maternal Aneurysmal Subarachnoid Hemorrhage During Pregnancy as an Interdisciplinary Task. *Maternale Subarachnoidalblutung in der Schwangerschaft als interdisziplinäre Herausforderung. Z Geburtshilfe Neonatol.* 2017; 221(6):276-282. doi:10.1055/s-0043-119363
2. Selo-Ojeme DO, Marshman LA, Ikomi A. Aneurysmal subarachnoid haemorrhage in pregnancy. *Eur J Obstet Gynecol Reprod Biol.* 2004; 116(2):131-143. doi: 10.1016/j.ejogrb.2004.04.016
3. Robba C, Bacigaluppi S, Bragazzi NL. Aneurysmal Subarachnoid Hemorrhage in Pregnancy-Case Series, Review, and Pooled Data Analysis. *World Neurosurg.* 2016; 88:383-398. doi: 10.1016/j.wneu.2015.12.027
4. Kataoka H, Miyoshi T, Neki R, Yoshimatsu J, Ishibashi-Ueda H, Iihara K. Subarachnoid hemorrhage from intracranial aneurysms during pregnancy and the puerperium. *Neurol Med Chir.* 2013; 53(8):549-554. doi:10.2176/nmc.53.549
5. Block HS. Neurological Complications of Pregnancy. *Curr Neurol Neurosci Rep.* 2016; 16(7):67. doi:10.1007/s11910-016-0665-2
6. Bateman BT, Olbrecht VA, Berman MF, Minehart RD, Schwamm LH, Leffert LR. Peripartum subarachnoid hemorrhage: nationwide data and institutional experience. *Anesthesiology.* 2012; 116(2):324-333. doi:10.1097/ALN.0b013e3182410b22
7. Beighley A, Glynn R, Scullen T. Aneurysmal subarachnoid hemorrhage during pregnancy: a comprehensive and systematic review of the literature. *Neurosurg Rev.* 2021; 44(5):2511-2522. doi:10.1007/s10143-020-01457-2
8. Kizilkilic O, Albayram S, Adaletli I. Endovascular treatment of ruptured intracranial aneurysms during pregnancy: report of three cases. *Arch Gynecol Obstet.* 2003; 268(4):325-328. doi:10.1007/s00404-002-0384-6
9. Nussbaum ES, Goddard JK, Davis AR. A Systematic Review of Intracranial Aneurysms in the Pregnant Patient - A Clinical Conundrum. *Eur J Obstet Gynecol Reprod Biol.* 2020; 254:79-86. doi:10.1016/j.ejogrb.2020.08.048
10. Acciarresi M, Altavilla R, Mosconi MG, Caso V. Management of intracranial haemorrhage, unruptured aneurysms and arteriovenous malformations during and after pregnancy. *Curr Opin Neurol.* 2019; 32(1):36-42. doi:10.1097/WCO.0000000000000643
11. Marshman LA, Aspoas AR, Rai MS, Chawda SJ. The implications of ISAT and ISUIA for the management of cerebral aneurysms during pregnancy. *Neurosurg Rev.* 2007; 30(3):177-180. doi:10.1007/s10143-007-0074-8
12. Ishii A, Miyamoto S. Endovascular treatment in pregnancy. *Neurol Med Chir.* 2013; 53(8):541-548. doi:10.2176/nmc.53.541
13. Tarnaris A, Haliasos N, Watkins LD. Endovascular treatment of ruptured intracranial aneurysms during pregnancy: is this the best way forward? Case report and review of the literature. *Clin Neurol Neurosurg.* 2012; 114(6):703-706. doi: 10.1016/j.clineuro.2011.11.025
14. Lee KH, Lukovits T, Friedman JA. "Triple-H" therapy for cerebral vasospasm following subarachnoid hemorrhage.

Neurocrit Care. 2006; 4(1):68-76. doi:10.1385/NCC:4:1:068

15. Georgantopoulou C, Jha R. Intracranial aneurysm in pregnancy presenting as hyperemesis gravidarum. *J Obstet Gynaecol*. 2003; 23(1):74-5.

16. Roman H, Descargues G, Lopes M, Emery E, Clavier E, Diguët A, Freger P, Marpeau L, Proust F. Subarachnoid hemorrhage due to cerebral aneurysmal rupture during pregnancy. *Acta Obstet Gynecol Scand*. 2004; 83(4):330-4. doi: 10.1111/j.0001-6349.2004.00281.x

17. Riviello C, Ammannati F, Bordi L, Lamassa M, Mennonna P, Parretti E, Tondi F, Mello G. Pregnancy and subarachnoid hemorrhage: a case report. *J Matern Fetal Neonatal Med*. 2004; 16(4):245-6. doi: 10.1080/14767050400014469

18. Nelson LA. Ruptured cerebral aneurysm in the pregnant patient. *Int Anesthesiol Clin*. 2005; 43(4):81-97. doi: 10.1097/01.aia.0000182635.09197.e8

19. Darbhamulla SV, Reddy R. Subarachnoid haemorrhage in pregnancy. *J Obstet Gynaecol*. 2007; 27(1):80-1. doi: 10.1080/01443610601062630

20. Duggan T, Simpson A. An unusual intracranial aneurysm presenting in pregnancy. *Int J Obstet Anesth*. 2008; 17(2):194-5. doi: 10.1016/j.ijoa.2007.09.012

21. Tiel Groenestege AT, Rinkel GJ, van der Bom JG, Algra A, Klijn CJ. The risk of

aneurysmal subarachnoid hemorrhage during pregnancy, delivery, and the puerperium in the Utrecht population: case-crossover study and standardized incidence ratio estimation. *Stroke*. 2009; 40(4):1148-51. doi: 10.1161/STROKEAHA.108.539700

22. Pumar JM, Pardo MI, Carreira JM, Castillo J, Blanco M, Garcia-Allut A. Endovascular treatment of an acutely ruptured intracranial aneurysm in pregnancy: report of eight cases. *Emerg Radiol*. 2010; 17(3):205-7. doi: 10.1007/s10140-009-0848-0

23. Couldwell SM, Kraus KL, Couldwell WT. Regression of cerebral arteriovenous malformation in the puerperium. *Acta Neurochir*. 2011; 153(2):359-62. doi: 10.1007/s00701-010-0897-x

24. Elwatidy S, Jamjoom Z, Elgamal E, Abdelwahab A. Management strategies for acute brain lesions presenting during pregnancy: a case series. *Br J Neurosurg*. 2011; 25(4):478-87. doi: 10.3109/02688697.2010.550345

25. Doğan S, Salman MC, Deren O, Geyik S. Carotid-cavernous fistula in term pregnancy due to spontaneous rupture of carotid-cavernous aneurysm. *J Obstet Gynaecol Res*. 2012; 38(2):427-30. doi: 10.1111/j.1447-0756.2011.01703.x